Visualizing Ensembles for Effective Collaboration

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Organizations Fail to Exploit All Their Resources in Making Decisions

Complex Problems Often have many sources of useful information and knowledge:

- **Quantitative - databases and models**
- **Qualitative - knowledge and intuitions of experts and decision makers**
- **Organizational - procedures, protocols, organizational culture**

Integrating all these resources to support important decisions is hard and seldom accomplished

- **resources are in different offices, computers, and heads**
- **information of different type, resolution, or scope**
- **“knowledge” is often inconsistent - reflecting differing viewpoints, values, or inferred from different data**
- **Neither IT as communication nor digital oracles solve all problems**

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Classical Decision Theory is Part of the Problem

The Analytic Model

- **idealized monolithic decision maker**
- **who is consciously aware of all relevant knowledge**
- **who holds consistent and coherent values and preferences**
- **and is dealing with a closed system**
- **forecasts the outcome of all the available options and picks the one with the greatest (expected) value**
- **Typically results in static policy - no adaptation**

This framework is directly contradicted by the realities of organizational behavior

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Most Real decisions are dominated by Context and Pragmatics

Reasoning is fundamentally social

- **communication of arguments among community of decision makers and their supporting staffs**

Reasoning is often political

- **diverse stakeholders without consensus on probabilities, causal relationships, or values**

Many important problems involve Complex Open Systems

- **exogenous events can be important**
- **lists of important factors and uncertainties are not fixed**
- **forecasts are not reliable**

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Evolving Logic: Crafting New Tools for Reasoning about Uncertain Futures

A technology for developing and understanding ensembles of models, scenarios, and plans allows:

- **Creating "landscapes" for navigating plausible futures and revealing important scenarios;**
- **Discovering sets of options that are "good enough"**
- **Testing robustness to develop options with acceptable performance across widest range of possibilities**
- **Searching for challenge sets that reveal danger points and enable developing adaptive strategies.**

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Representing Ensembles Provides Multiple Benefits

Addresses Uncertainty

- **Capture range of plausible future situations**
- **Explicitly incorporate alternative models**

Supports Robust Planning

- **Robust to lack of knowledge (uncertainty)**
- **Robust to surprise**
- **Robust to differing beliefs/values among participants**

Promotes Human/Computer interaction - symbiosis

- **machines portray the plausible/feasible**
- **humans focus, prune, refine, select**

Can be used to promote Human-to-Human interaction and collaboration as well

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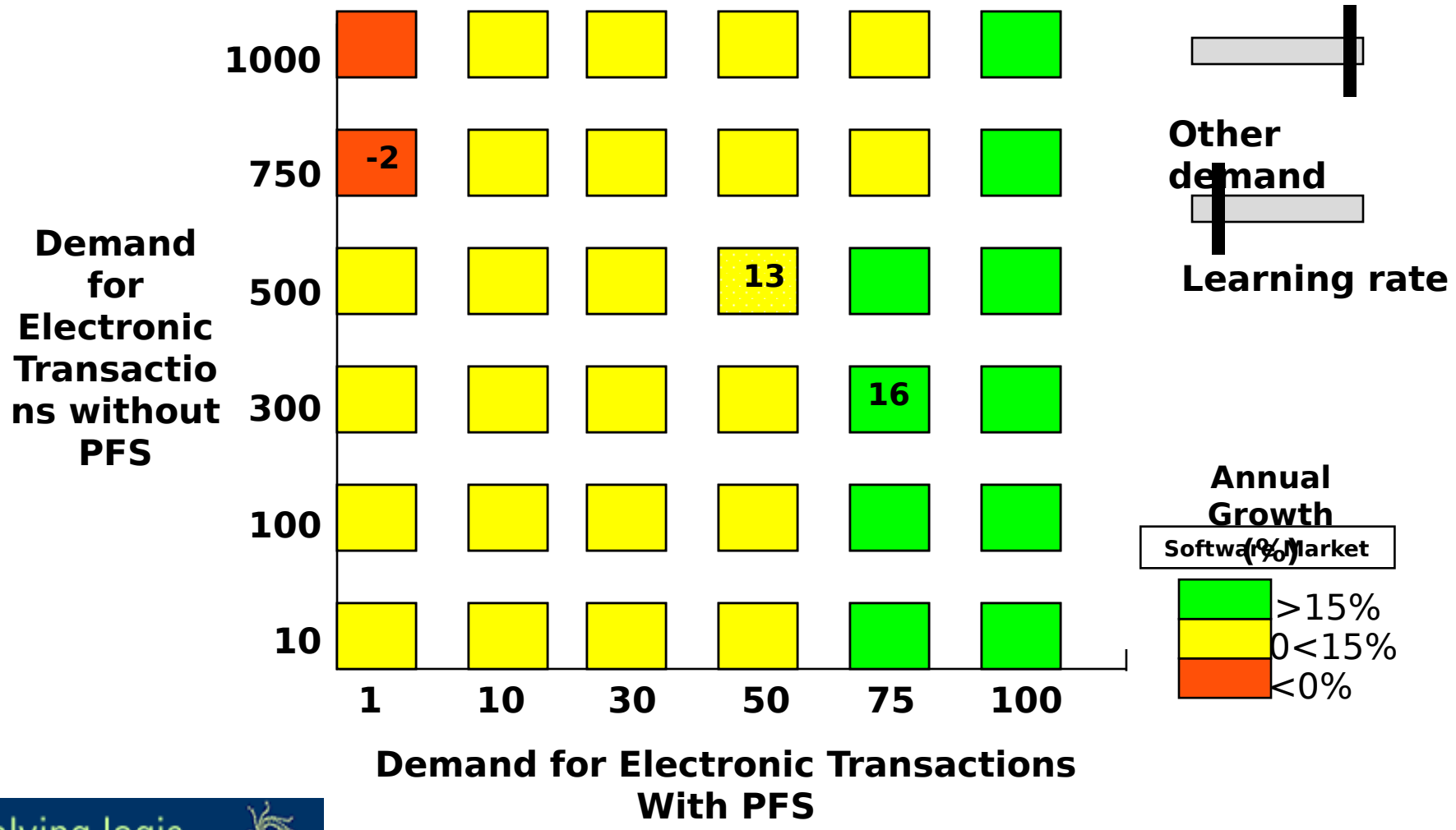
Landscapes Lay Out Alternatives Provide Orientation



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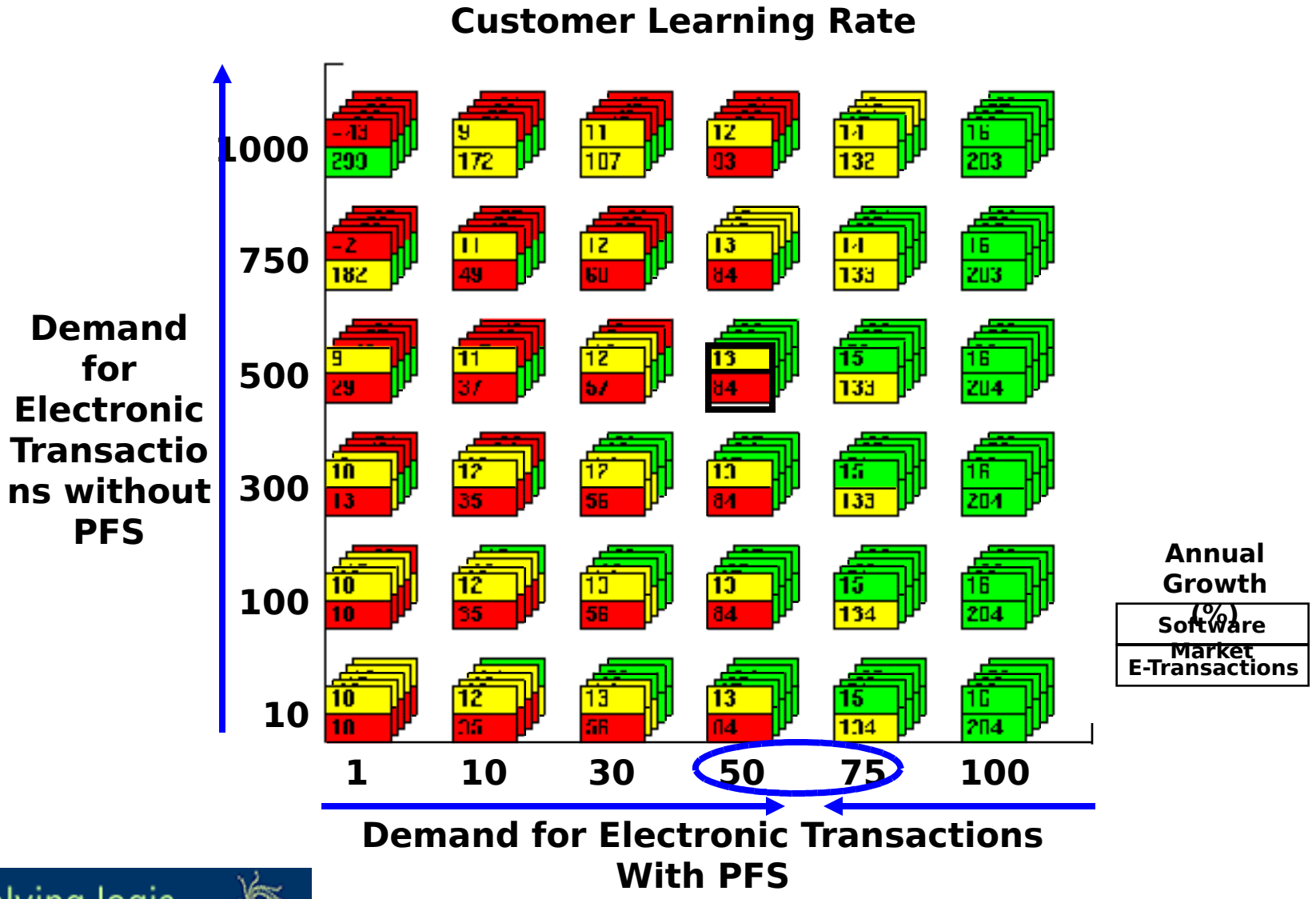
Range of Plausible Futures



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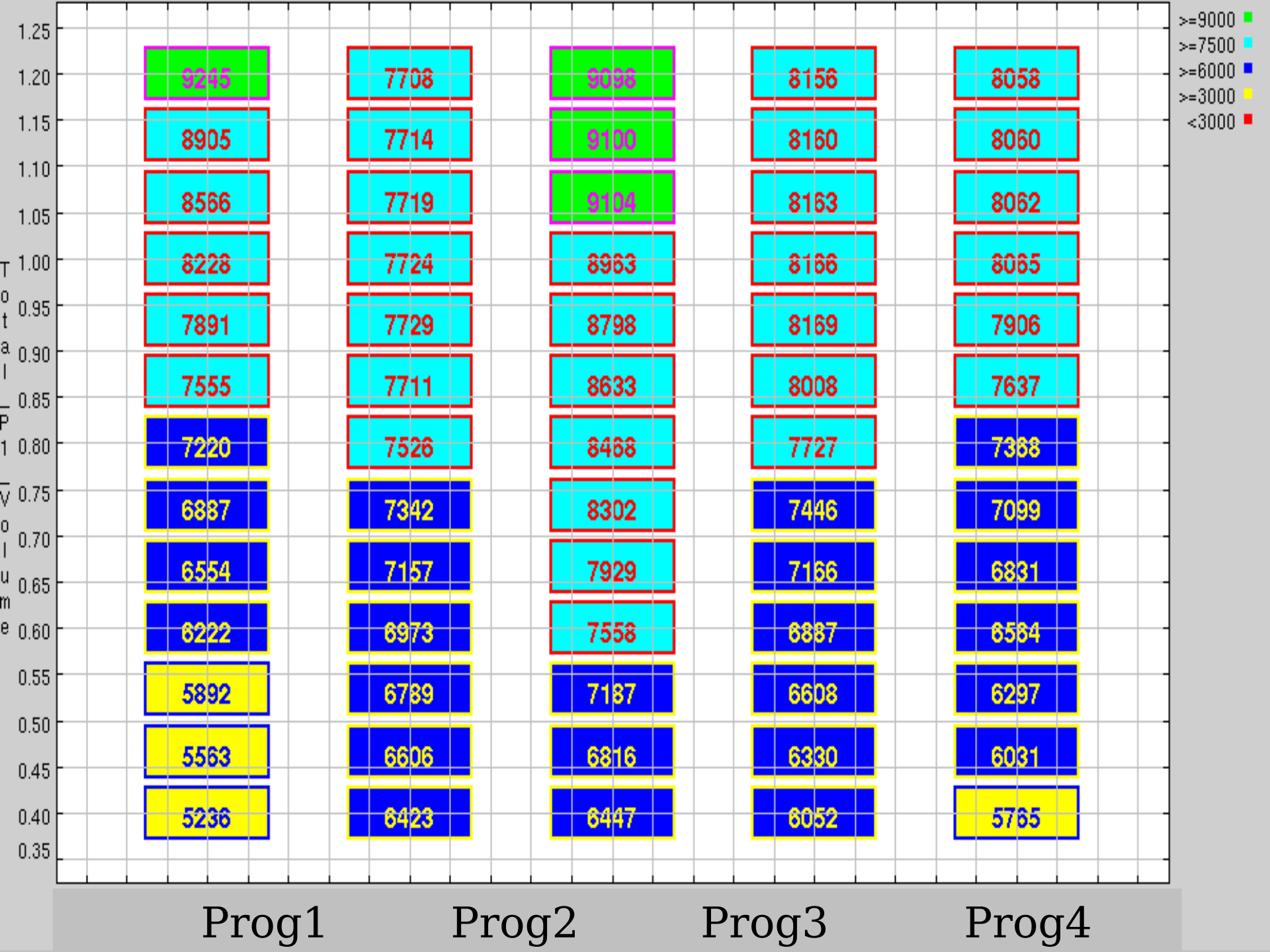
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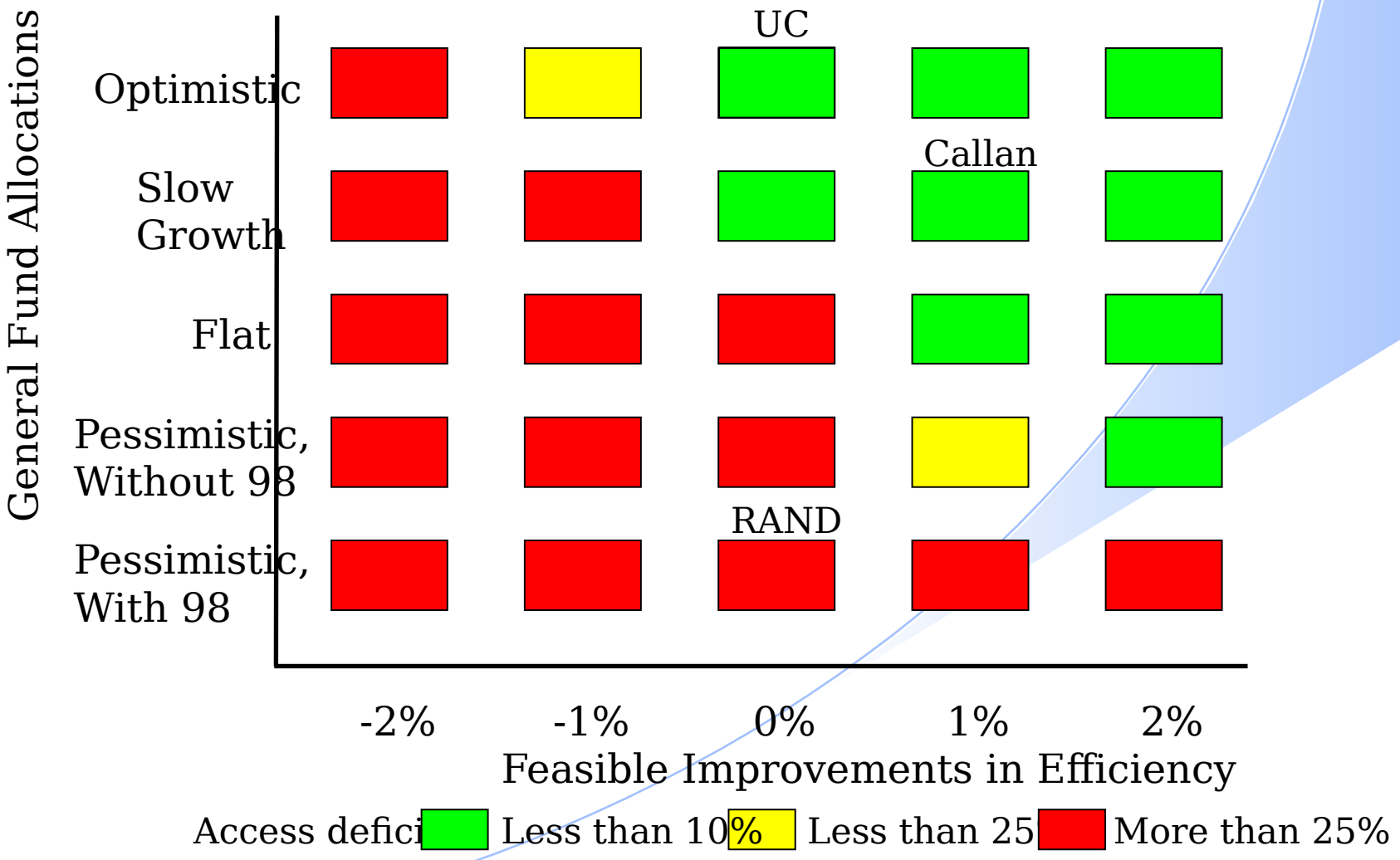
Setting Alternative Scenarios in Context



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Classical Decision Analysis Impedes Collaboration

Assess the services' deep attack systems to determine the appropriate weapon mix and force size

For any given scenario:

- **Targets**
- **Weapons**
- **Platforms**
- **Test Data**
- **Special Features** ...

Find Optimal Solution:

Example: Campaign in Country *X* in Year *Y* is completed in 22 days

Using:

- **TOTAL Weapon 1 USED: 15,502**
- **TOTAL Weapon 2 USED: 6,960**
- **TOTAL Weapon 3 USED: 5,003**

Computer's Recommendation is "Take it, or Leave it"

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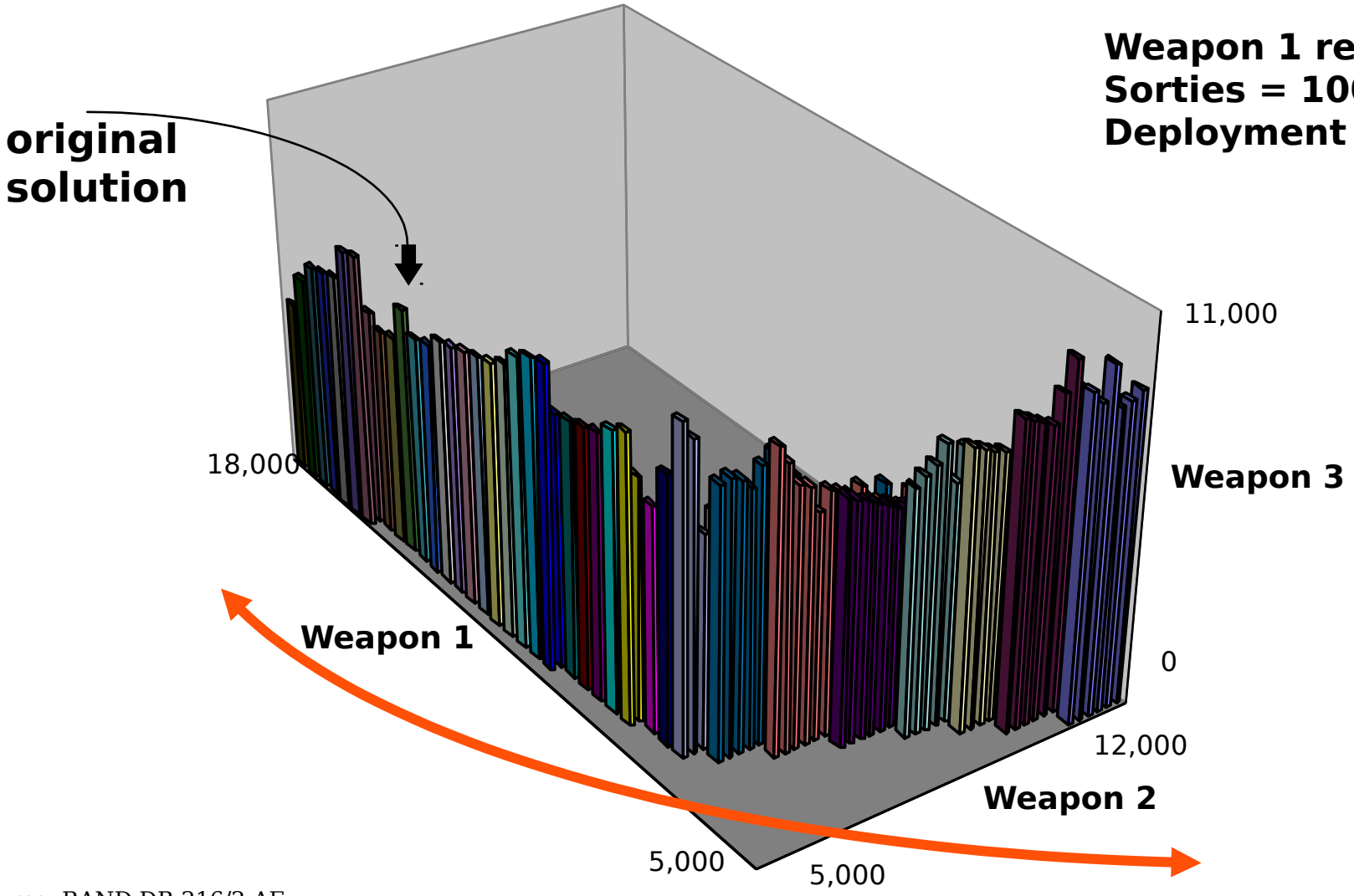
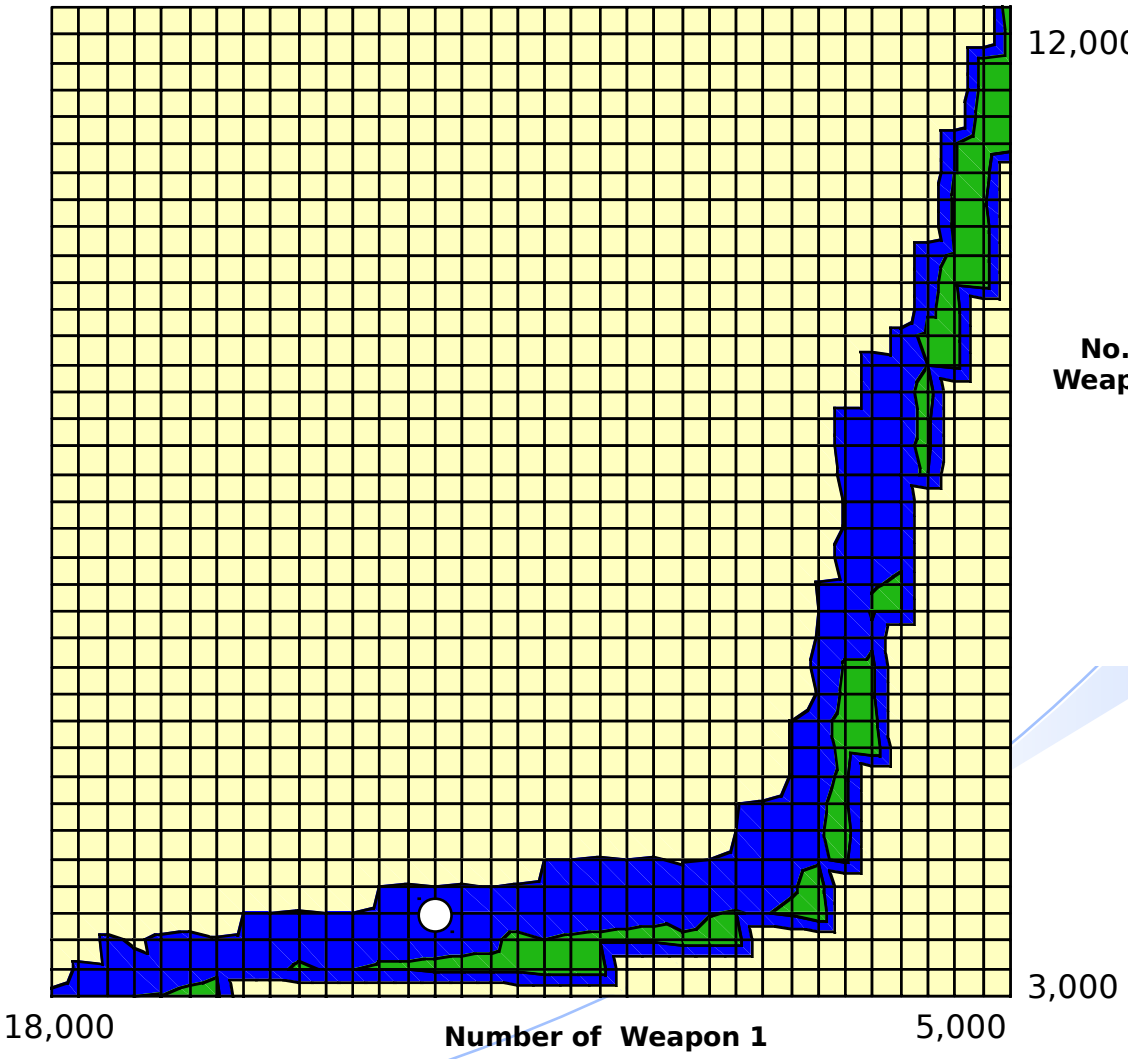
View Level Sets: A Selection of "Good Enough" Alternatives Appear



Source: RAND DB-216/2-AF

Level Set Visualization Provides Backdrop for Collaborative Discussion



Weapon 1 rel. = 100
Sorties = 100%
Deployment = 100%

○ - original solution

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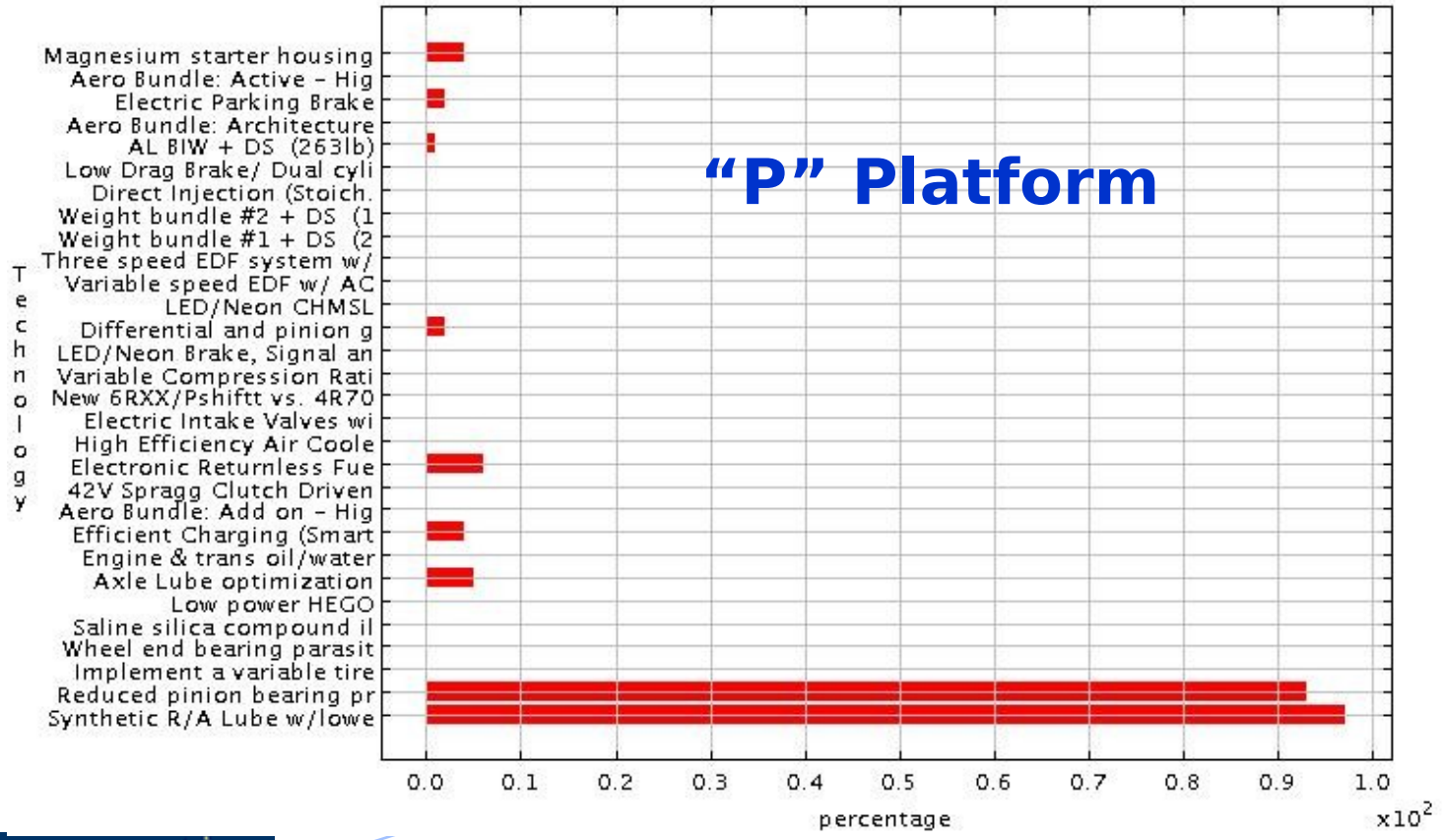
Craft Suitable Visual Language to Display Higher Dimensional Level Sets

1) Histogram of utilization -- How often does a FE t appear across a set of deployments?



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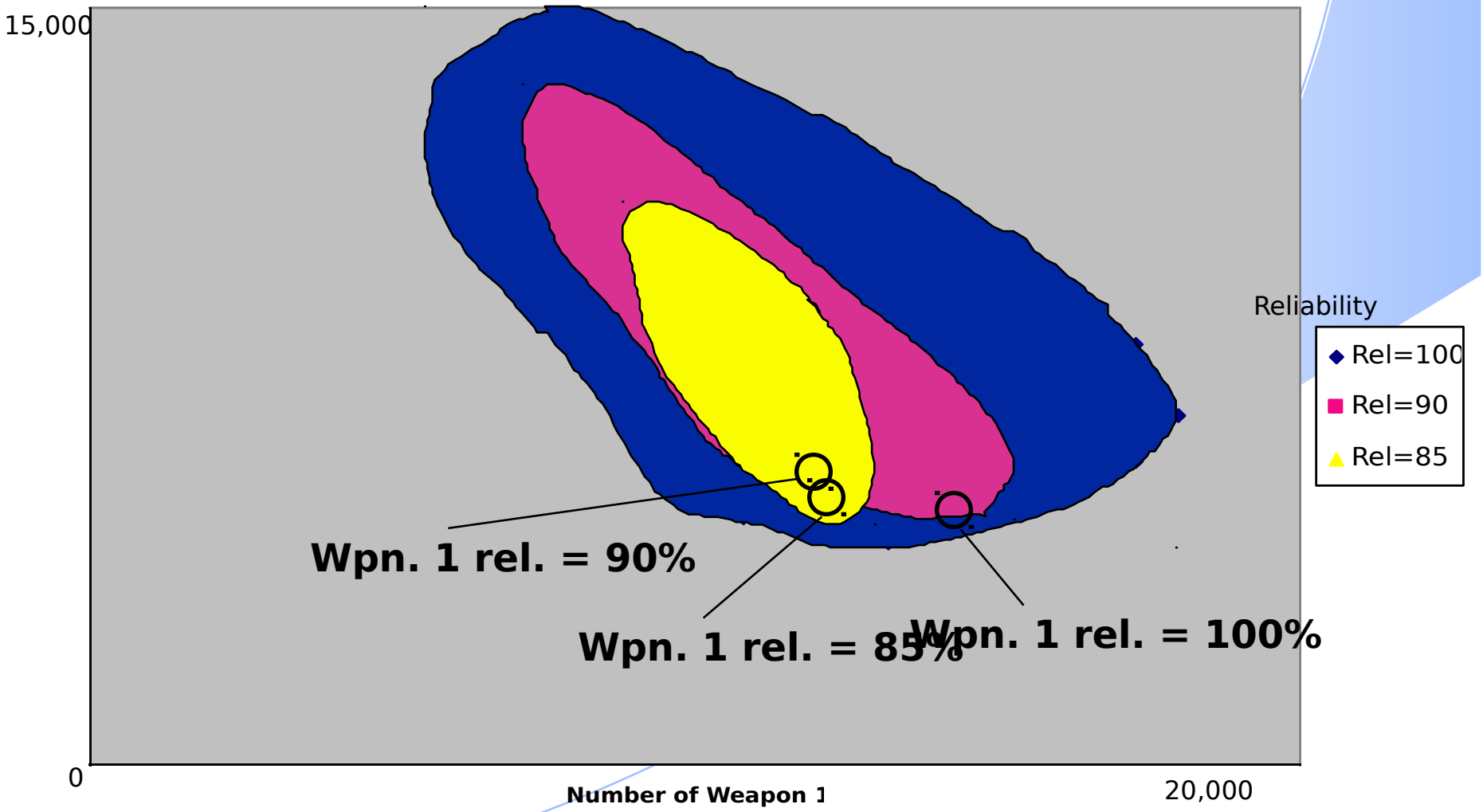
Intersect Level Sets to Seek Robust Options

Weapon 1 Reliability = 100%, 90%, 85%



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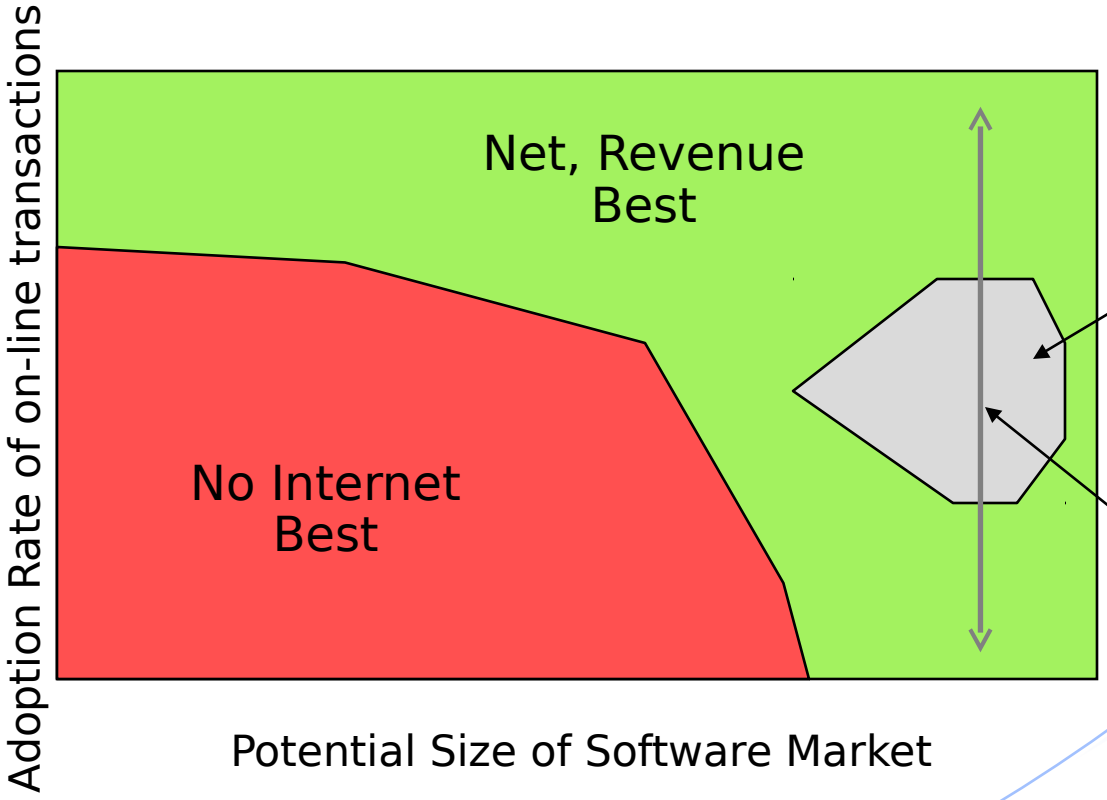
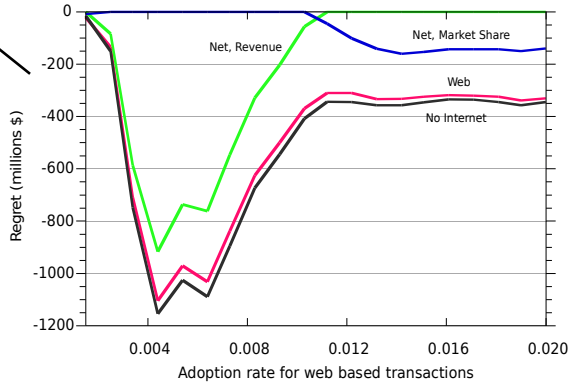
Search for High Regret Cases Yields Regime with Qualitatively Different Behavior



Net, Market Share Best



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To Succeed in the Face of Deep Uncertainty, Organizations Must...

- **Be Flexible -- Navigate uncertain space by recognizing change and taking appropriate actions.**
- **Retain Options -- Reduce exposure to past bad choices; enhance exposure to good prospects.**
- **Respond to New Input -- Adapt actions in light of updated information and other feedback.**
- **Turn Information into Knowledge -- Make fullest use all available data to inform and guide strategy.**
- **Attune the Organization -- Fully share knowledge and expertise throughout organization's structure.**

The Key: Seek "Robust", Adaptive Strategies

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Using Computers to Help Craft Adaptive Strategies

- **Combine strategies that perform well under differing circumstances with logic that picks among them based on future information**
- **Test ensembles of alternative adaptive strategy options against ensembles of possible future conditions (challenge sets)**
- **Search for cases that break candidate strategies**
- **Use robust region analysis to identify limits of candidate adaptive strategies**
- **Iterate, combining human and machine resources to devise the most robust adaptive mechanism**

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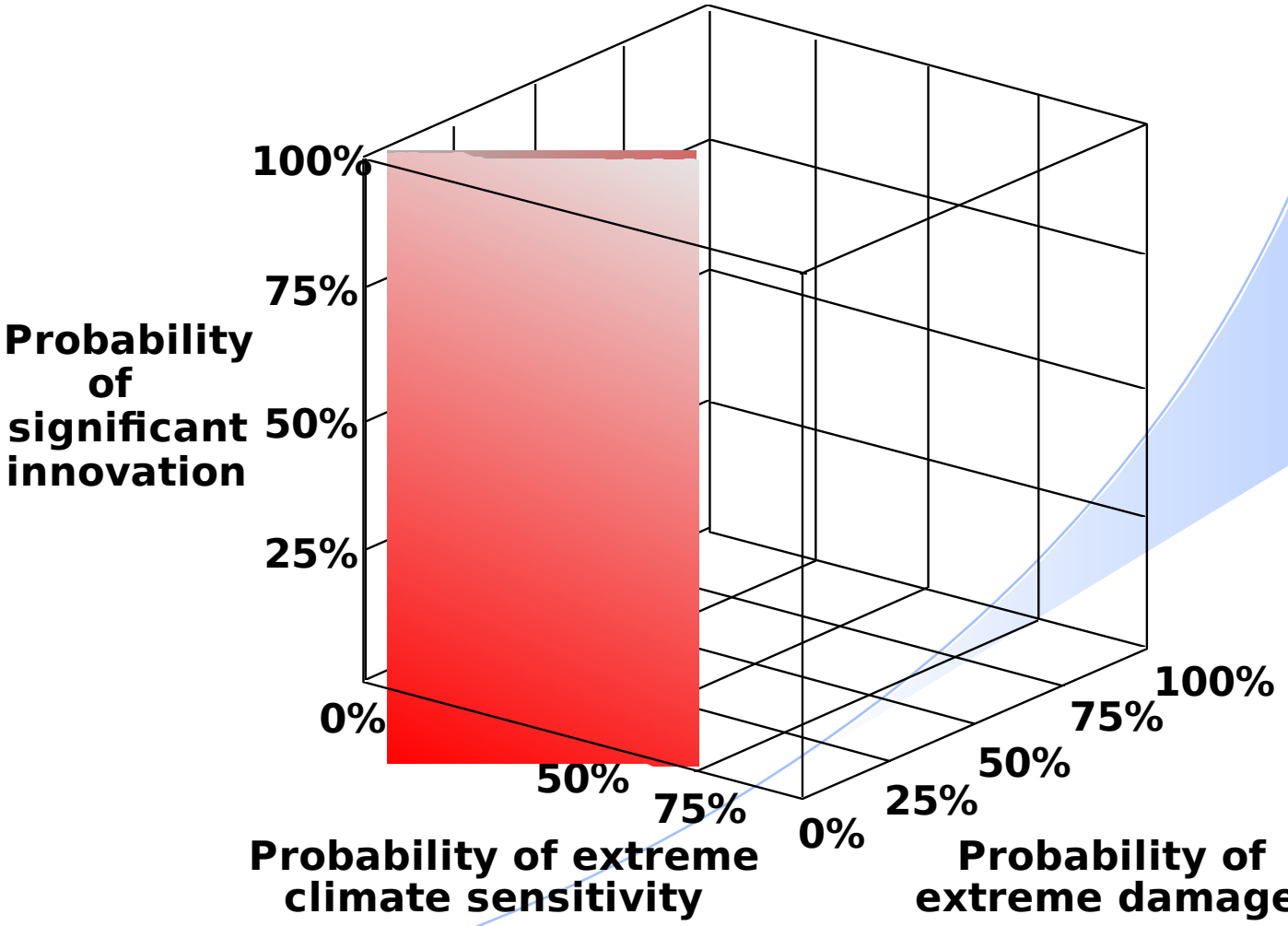
Traditional Approaches Often Present Unpalatable Dichotomies of Choice



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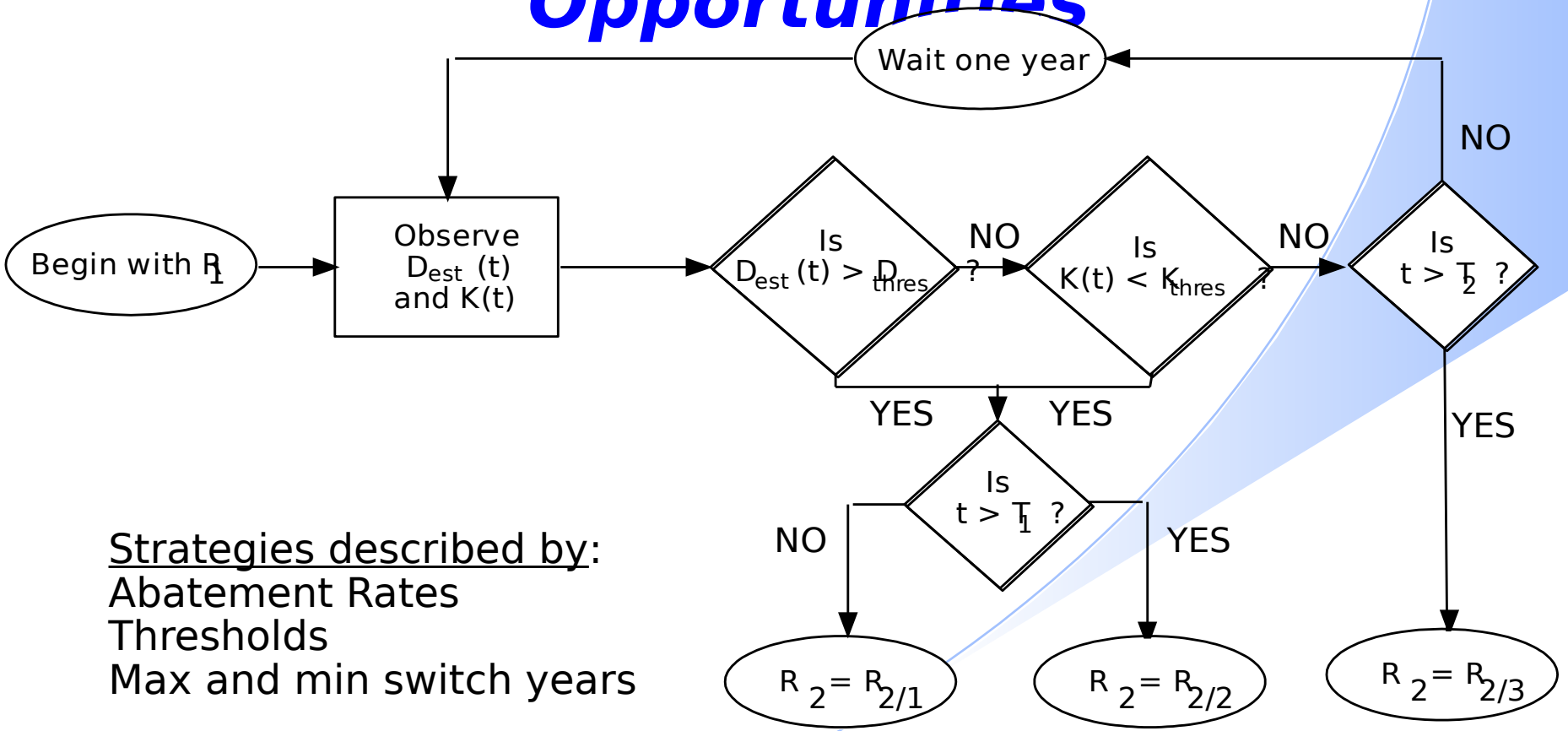
Adaptive-Decision Strategy Responds to Dangers and Opportunities



Strategies described by:
Abatement Rates
Thresholds
Max and min switch years

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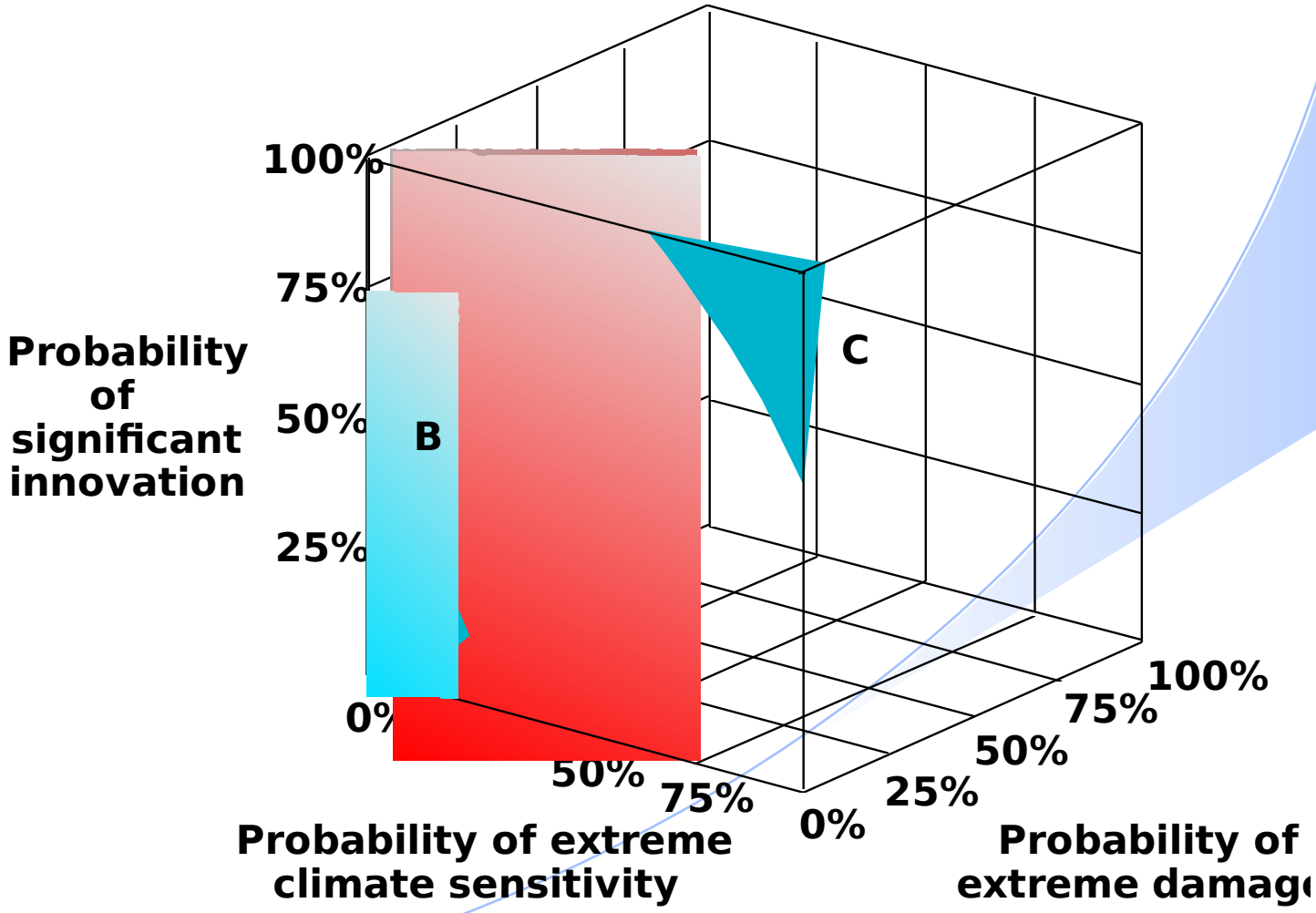
An Adaptive Strategy Dominates



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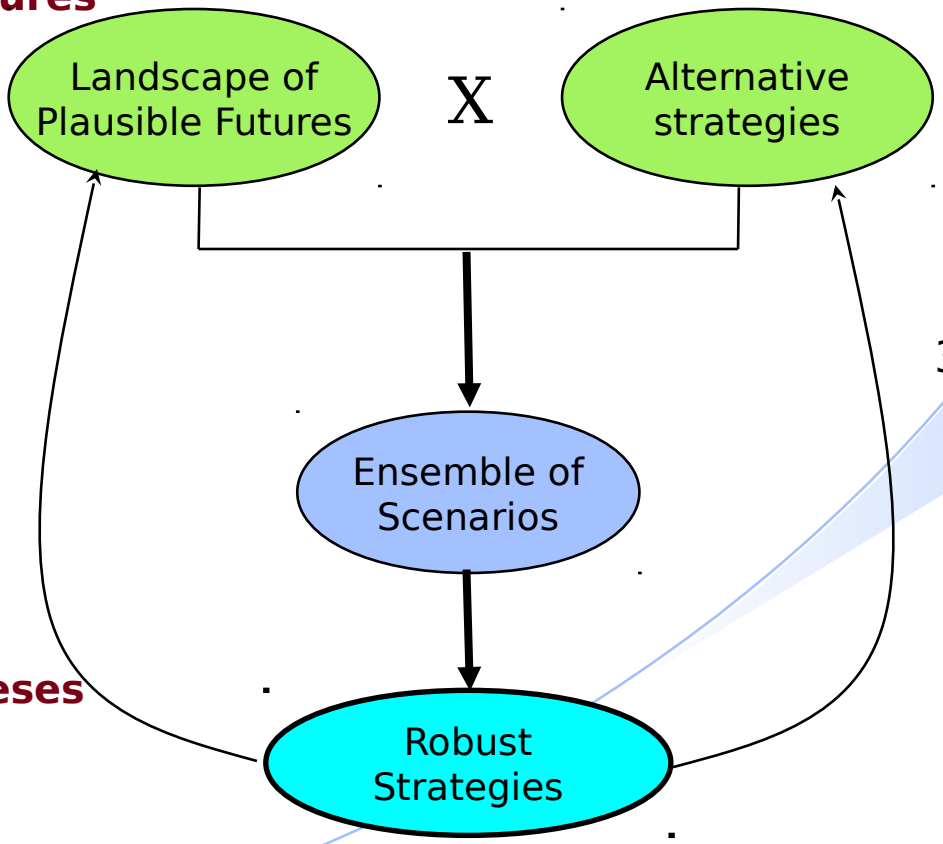
Adaptive interaction is also key to finding robust conclusions

1) **Choose models that span the full range of plausible futures**



3) **Test hypotheses by searching back over futures and strategies**

2) **Make hypotheses about robust strategies**

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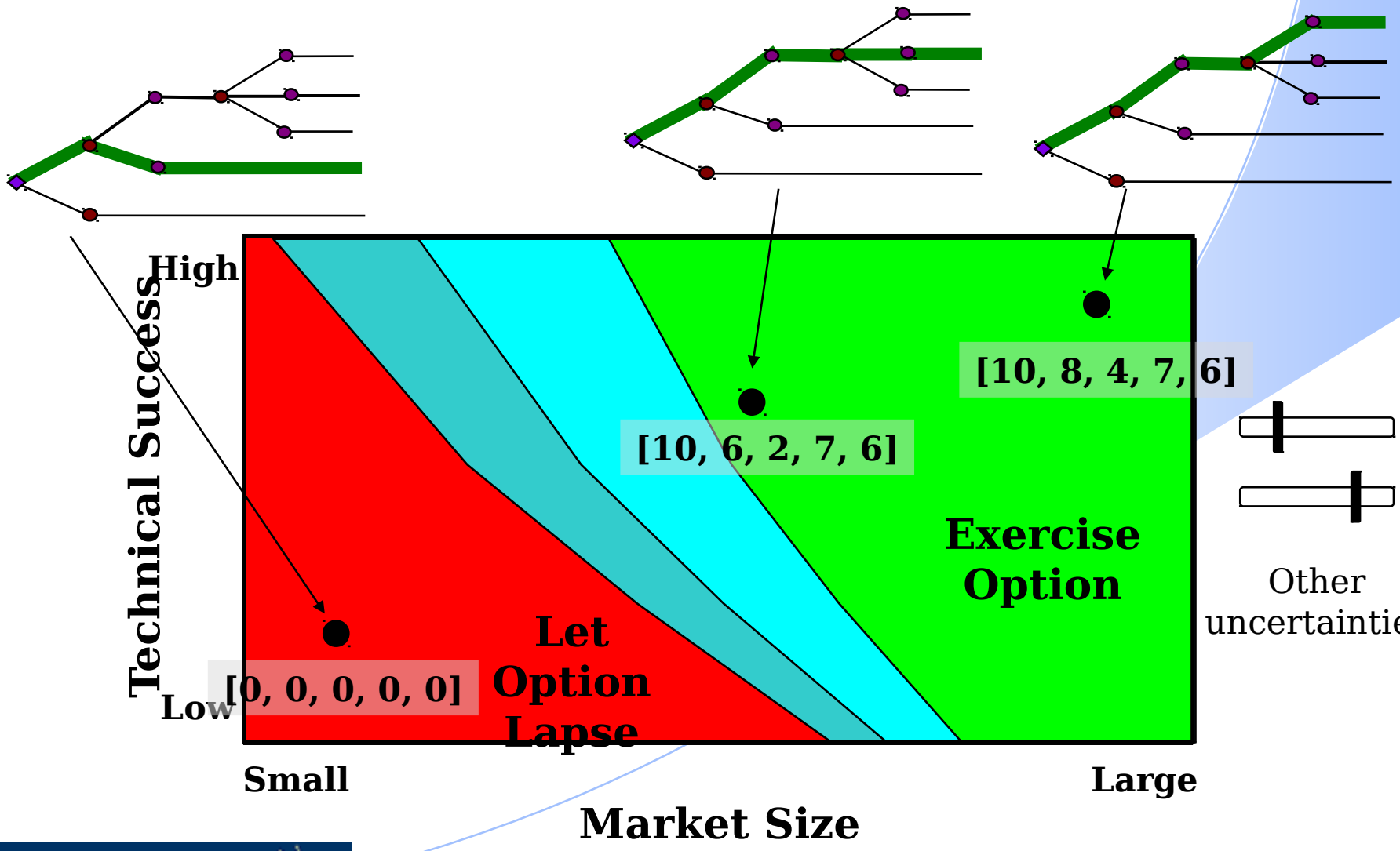
Drilling Down on Landscapes Reveal Value of Adaptive Options



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Computer Assisted Reasoning system (CARs)

- General purpose environment for reasoning with large numbers of computational experiments
  - Can exploit arbitrary models
  - Provides a library of computational services
    - including interactive visualization of computed ensembles
- CARs 2.0 (Carmen) under development (alpha testing in 2002)
- Designed as Desk-top Robust Adaptive Planning System
- Could be extended to support distributed collaboration
  - Options for distributed operation incorporated in foundation classes
  - Full multi-threaded support for concurrent experimental contexts

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Back Up Slides

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Evolving Logic Builds Software for Computer Assisted Reasoning

Computer Assisted Reasoning® (CAR™):

revolutionary software support for *robust, adaptive planning* under conditions of complexity and deep uncertainty

Deployed for a wide variety of clients, including:

- **Ford Motor Company (technology planning)**
- **Volvo Car Company (product planning)**
- **Los Alamos National Laboratories (strategic planning)**
- **DARPA (behavioral modeling)**
- **DoD, Air Force, DoE, NSF, NOAA (via RAND)**
- **States of California, Kentucky, Texas, and Nevada (via Council for Aid to Education)**

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Decision Makers Naturally Seek Robust, Adaptive Plans under Deep Uncertainty

Yet, traditional analyses do not provide support for this type of reasoning.

Most quantitative analyses are attuned to developing:

- **best models**
- **"best" guess, single-point estimates and solutions**

And use:

- **selections from available information**
- **assumptions as substitutes for uncertainties**
- **non-complex models of interaction**

The end result is often a highly abstract product yielding unclear (or erroneous) strategic directions

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There are Classes of Factors to Explore

Uncertainties Outside Control

- Competitors coming to market with similar offerings
- Availability of needed Class A composites by 2015
- Consumer preferences: styles, offers, functionality
- World / local economies
- Oil and gasoline prices, taxes
- Competitors' strategies
- Structure of demand; change in taste
- Technological discontinuities...

Levers Under Control

- Number of base XXXs
- Design number of variants for each base XXX
- Order and timing of introduction
- Scale of production
- Marketing strategies
- Revenue/pricing strategies
- Siting of production, distribution, re-work
- Partnering strategies...

Objectives and Measures

- TARR and NPV
- Cash position by year, VCC
- Entry ticket
- Margin; profitability; SAV
- Real options value of XXX
- Fixed costs as share of total costs
- Establishing new niches with new market share
- Reductions in time to market
- Sales volume
- External "brand" perception...

Relationships Between Fac

- Costs to produce variants under XXX regime
- Relation between number of variants and sales
- Relate demand, customer preferences to flexibility in manufacture
- Change in traditional levers (e.g., related to of under XXX regime
- Improved reconnaissance: buy out uncertainti
- Changes in secondary market price behavior
- Lead times
- Technical input/output relationships
- Relation between marketing and demand/sales

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Landscapes of Plausible Futures: Beyond the Base Case

Prediction or forecasting is an important and powerful form of model use

Computational poverty meant that until recently, it was often the only feasible form of model use

Frequently, models are used as though they predict, even when they have not been experimentally validated

This can result in misleading conclusions (and other ills)

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A Revolution in Computer Assisted Reasoning

Traditional Approaches to Decision Support and Policy Analysis are rooted in the pragmatics of computational poverty

Plentiful computing power now makes possible novel approaches based on the ability to conduct large numbers of computational experiments

- → **New Options for confronting uncertainty and r**
- → **Power for understanding complexity and non-l**
- → **Bridging between quantitative and qualitative approaches to problem solving**
- → **Integrating computer analysis with real world**

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CAR Enhances Use of Models When Predictions are Imperfect

- Allows users to use models facilely to create a range of plausible, critical scenarios and to understand the key drivers behind those scenarios
- Helps users integrate quantitative and qualitative data and thus make full use of available information
- Supports group decision making with interactive computer visualizations

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CAR Provides Quantitative Support for Robust Adaptive Planning (RAP)

- In a complex, uncertain, and dynamic world, decisions cannot be merely efficient or optimal, they must be robust
- Decision-makers naturally seek robust, adaptive plans in the face of deep uncertainty
- Advancing information technology enhances the use of adaptive plans to achieve robustness
- Evolving Logic's CAR technology is the first decision-support system specifically designed to provide quantitative support for Robust Adaptive Planning (RAP)

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Policy Analysis for Complex Adaptive Systems Requires New Tools

Naive Policy Analysis:

- **Develop best model of policy system**
- **Determine recommended policy by calculating optima of some cost function on that model**

Does not work well for complex systems because

- **Classical simulation modeling techniques do not exploit the information available about the behavior of complex systems**
- **"Best estimate" models cannot predict the behavior of complex systems**
- **"Optimal"policies often perform poorly - not robust**
- **Complex adaptive systems require adaptive polices**
  - **Knowledge, learning, and information processes undervalued in most policy studies**
- **Complex open systems ==> imply deep uncertainty**

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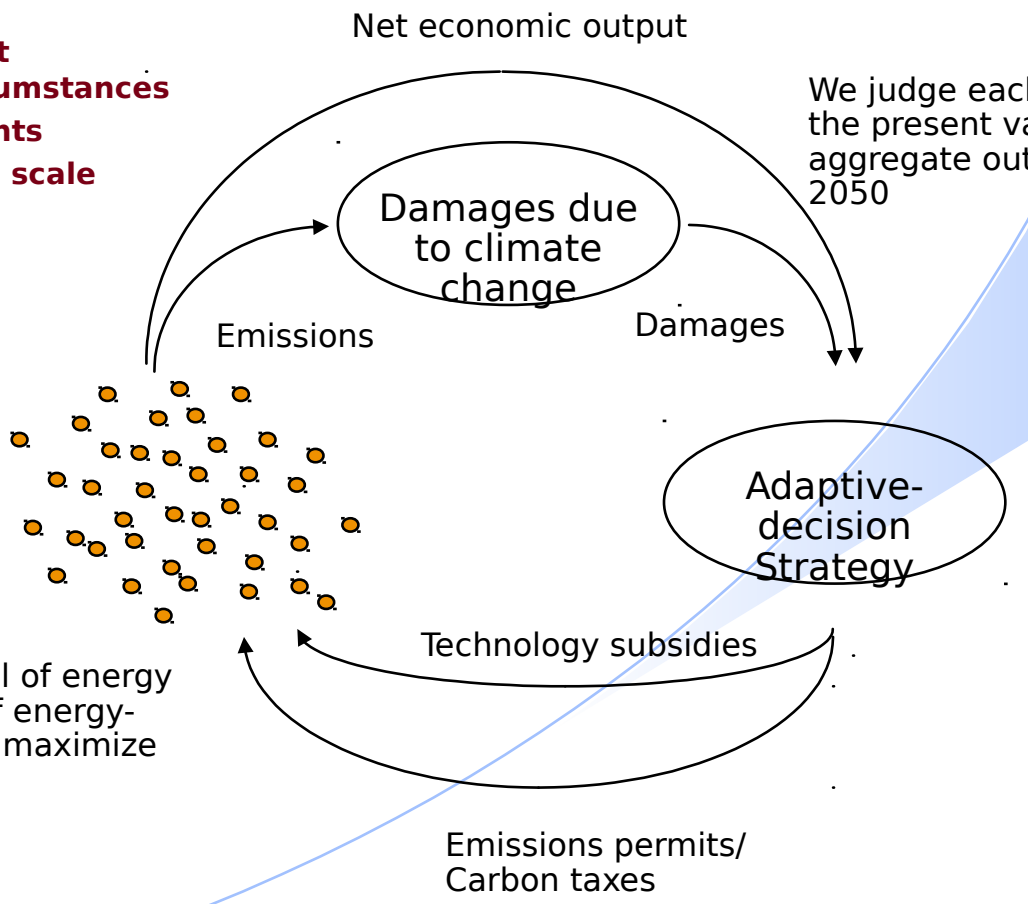
Agent Model Treats Externalities Thought to be Important to Technology Diffusion

Model represents:

- **Heterogeneous agent preferences and circumstances**
- **Learning among agents**
- **Increasing returns to scale**


Net economic output
We judge each scenario by the present value of aggregate output through 2050
Damages due to climate change
Emissions
Damages
Adaptive-decision Strategy
Economic Agents
Technology subsidies
Each agent chooses level of energy consumption and type of energy-producing technology to maximize its forecasted utility
Emissions permits/ Carbon taxes

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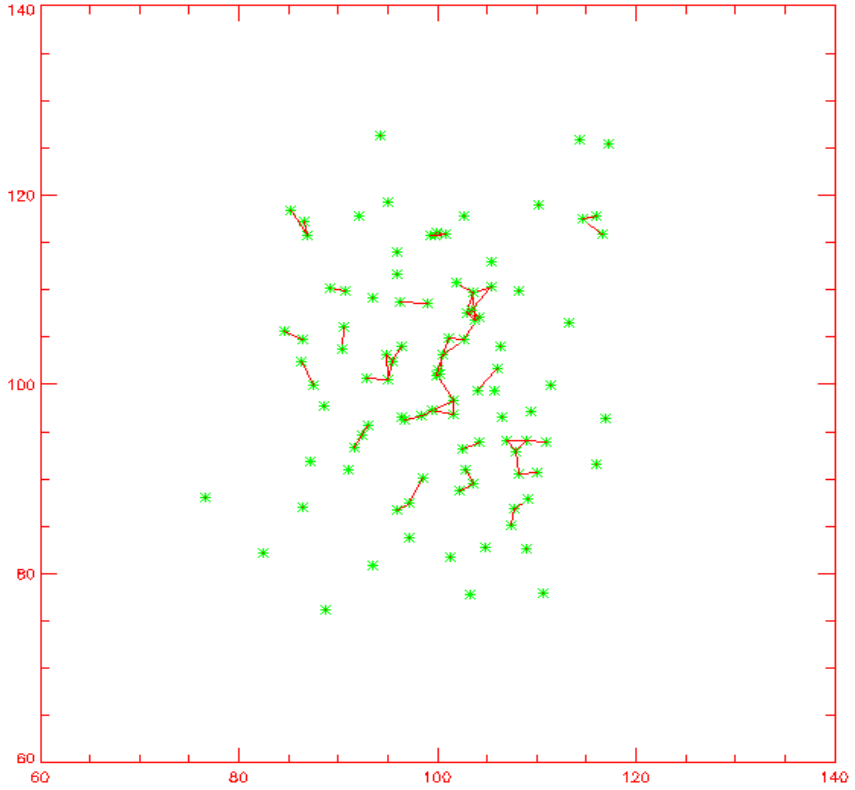
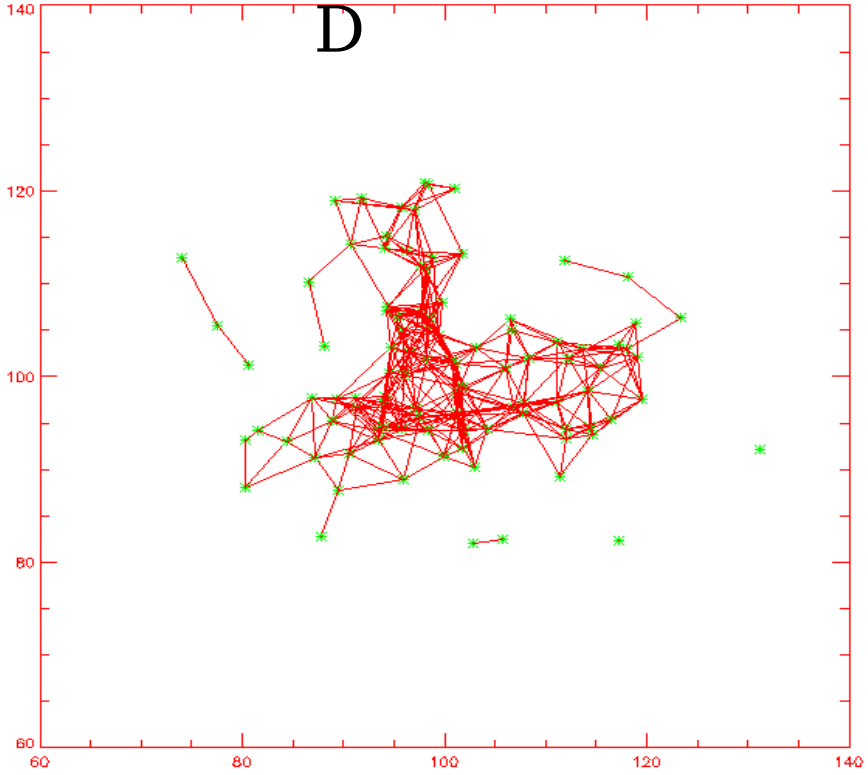
Information Flows Can Differ By Region

LCD



Low Connectivity

OECD



High Connectivity

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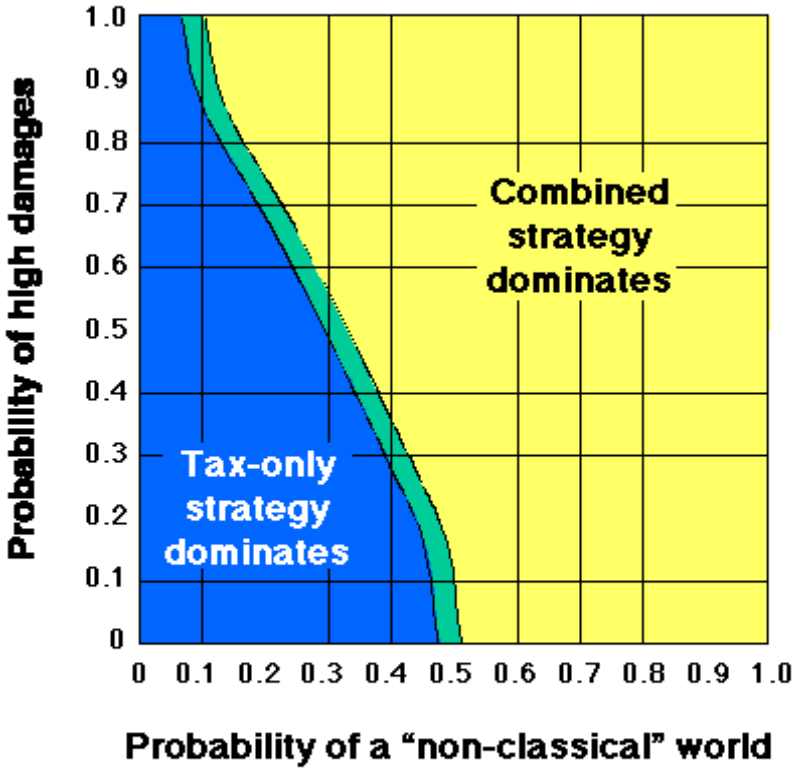
Exploring Alternative Behavior Rules in Agent-Based Models



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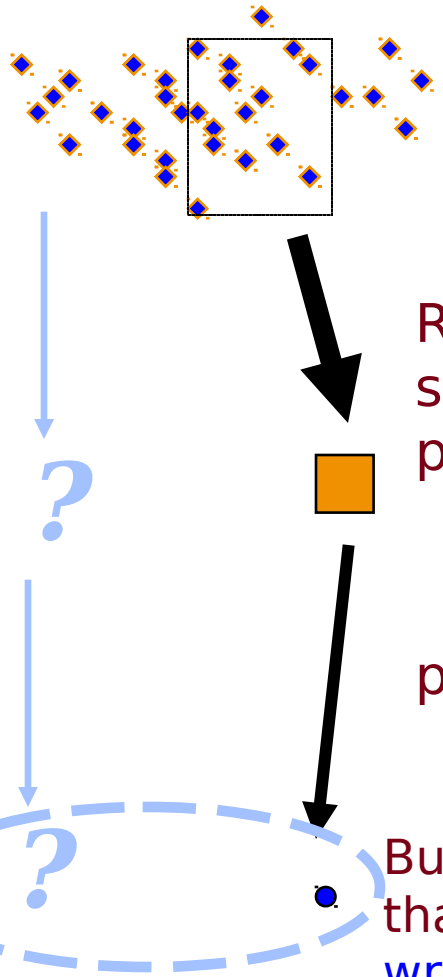
Why Do Trusted, Traditional Quantitative Tools Fail?



Firms have considerable information available

Only part is used so as to create *knowledge*

Rigorously sophisticated models are developed, submitted to computers, yielding single-point, best estimate "forecasts".

Decisions are taken based upon this prediction.

This approach works quite well, under the right conditions.

But when you are forced to pretend you know more than you really do, you might receive no answer, the wrong answer, or only one of many right answers.

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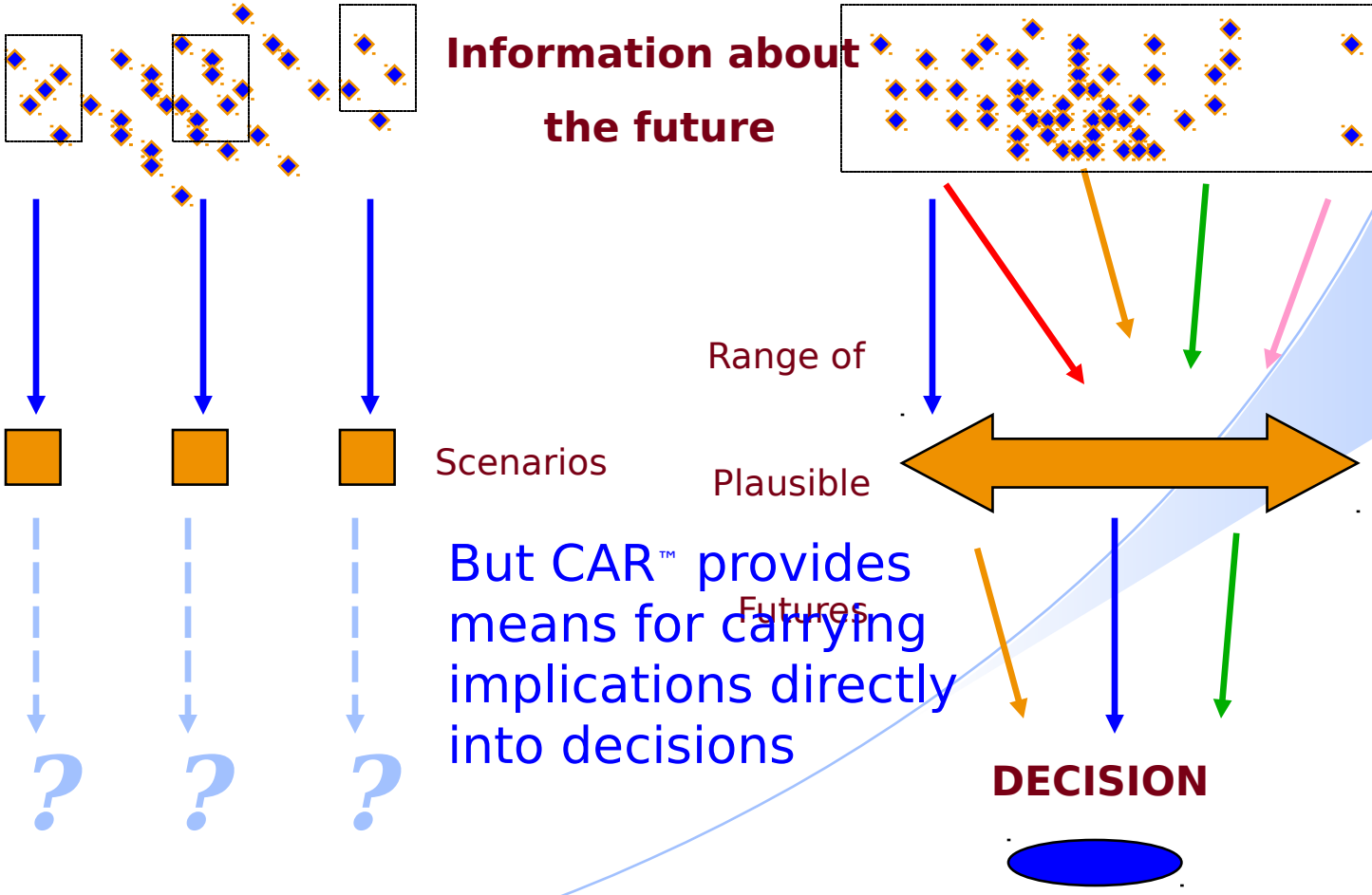
CAR™ Yields a Useful Cross Between Quantitative Analysis and Scenario Planning

Scenario Planning

Computer Assisted Reasoning™



But CAR™ provides means for carrying implications directly into decisions

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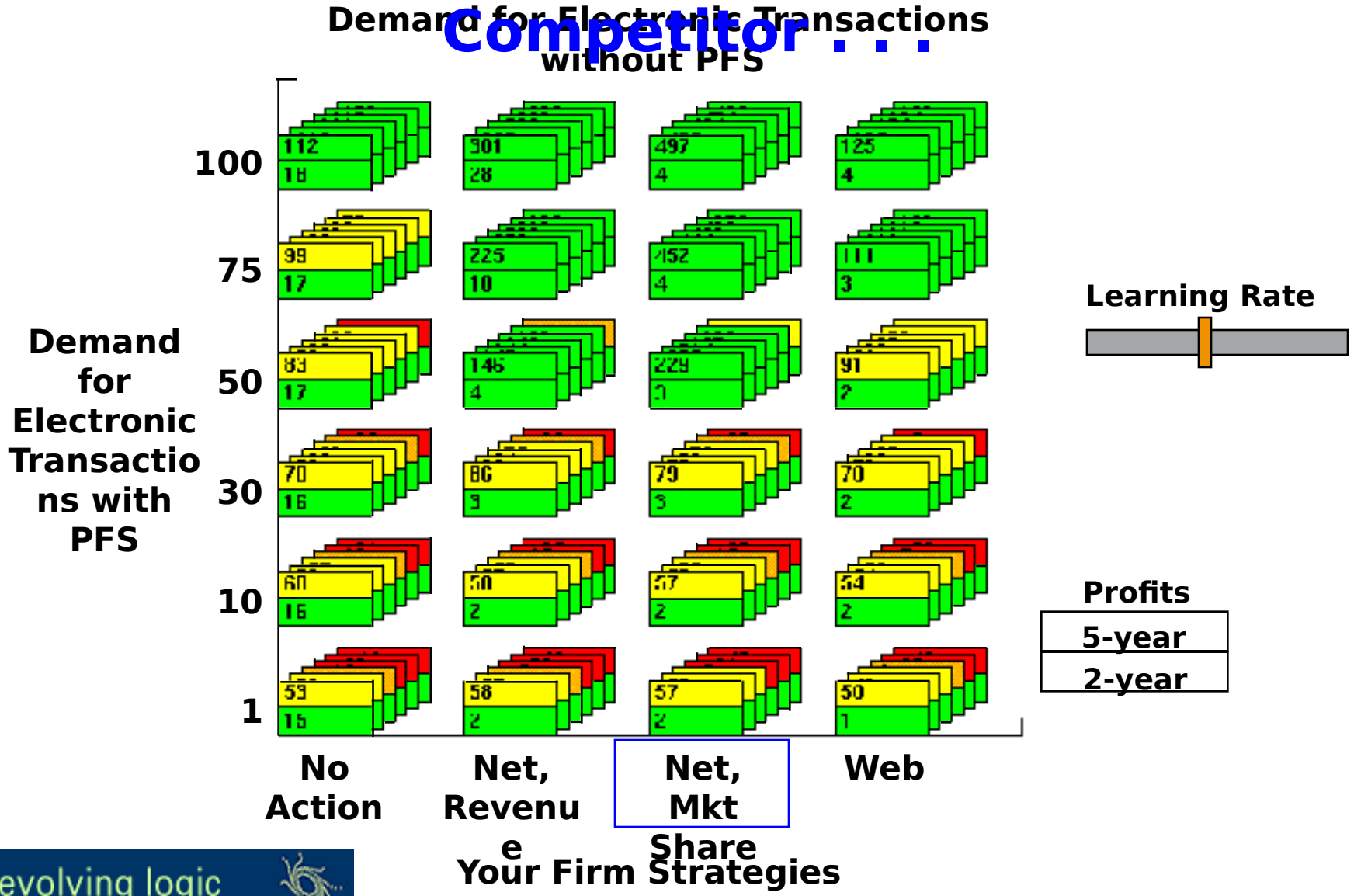
The Net/Market Share Strategy Produces Highest Operating Profits Against a Passive Competitor . . .



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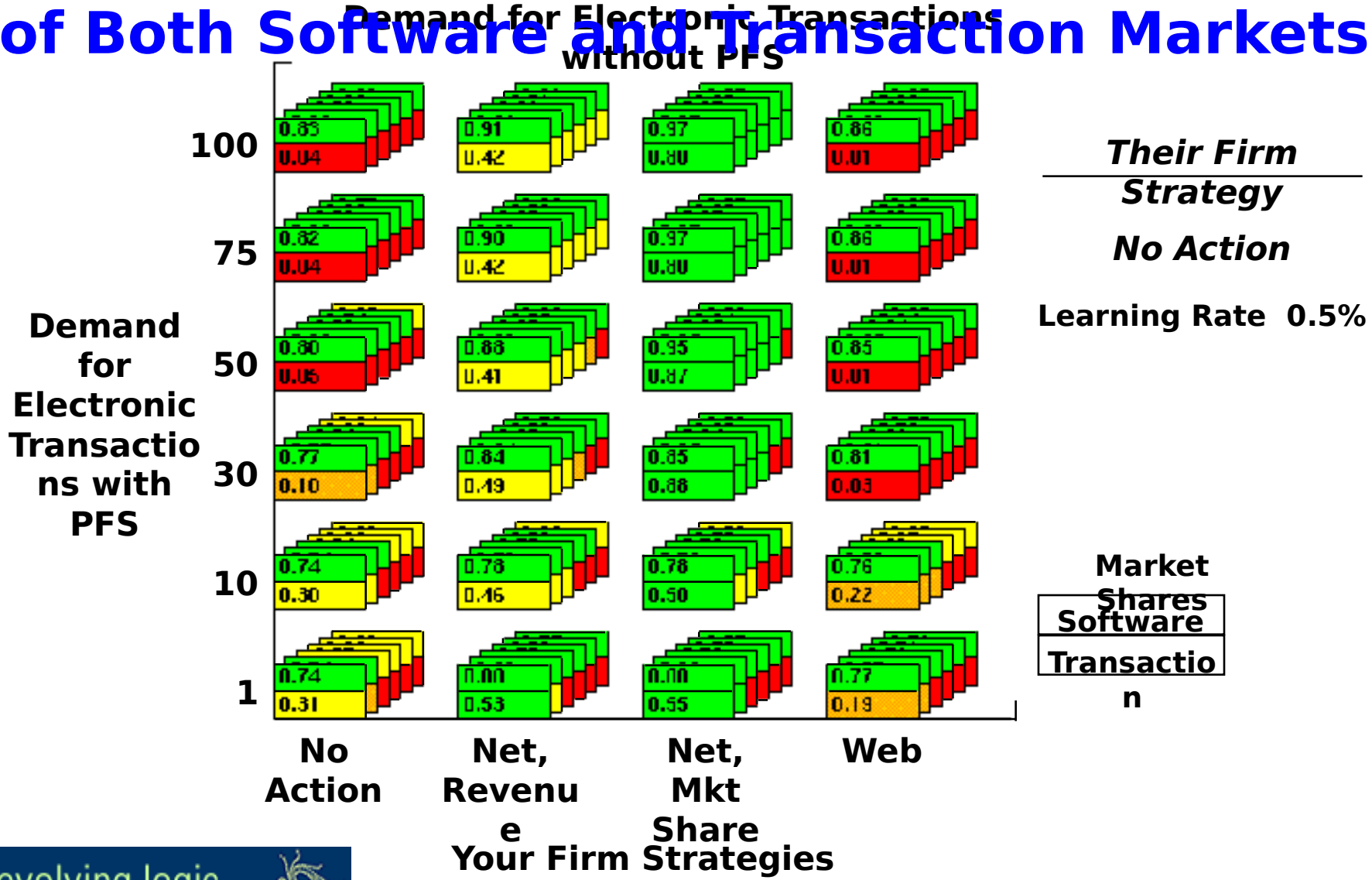
. . . As Well as Allowing Complete Dominance of Both Software and Transaction Markets



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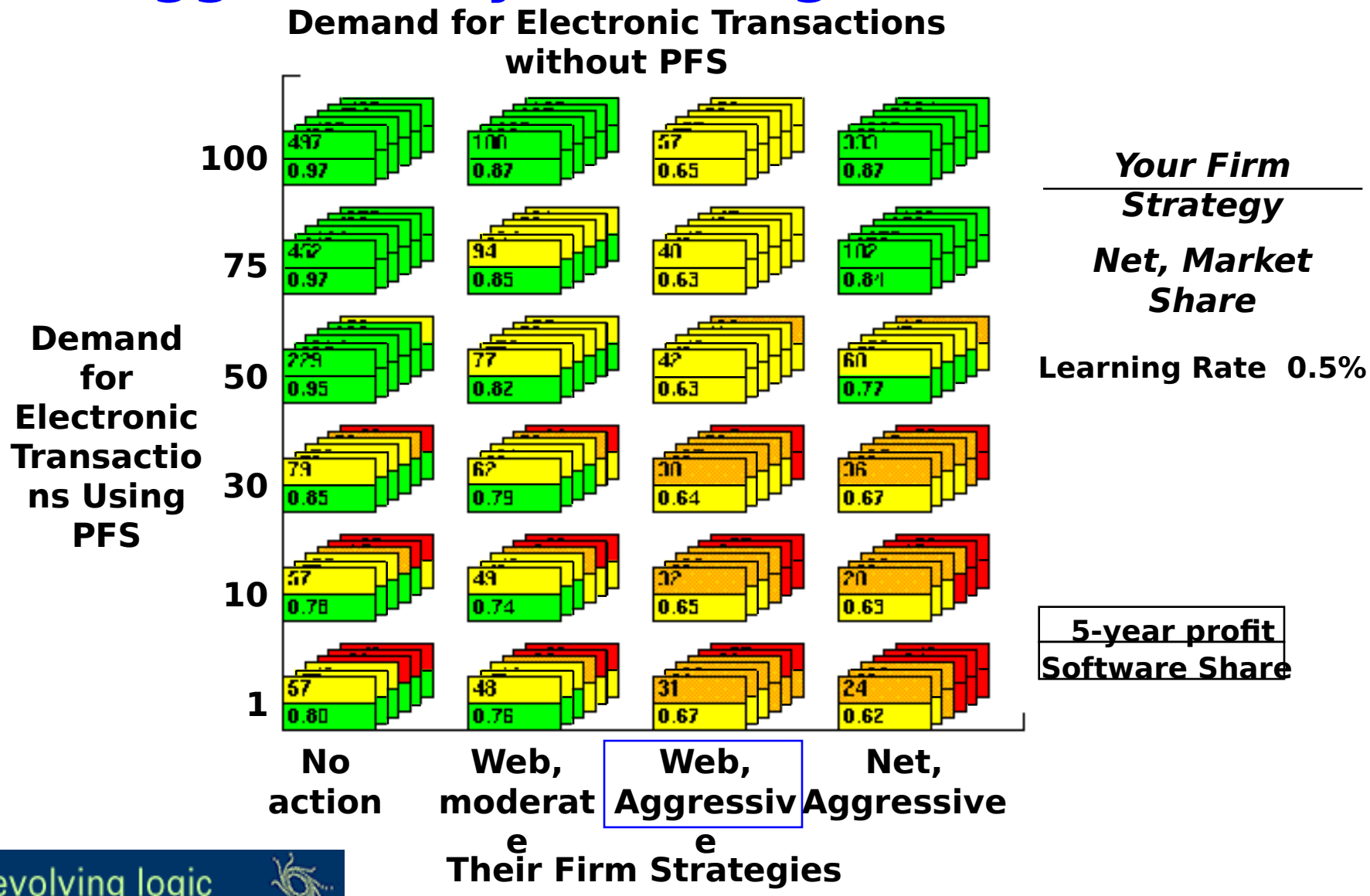
Your Competitor's Best Strategy Is Aggressively Pursuing the Web . . .



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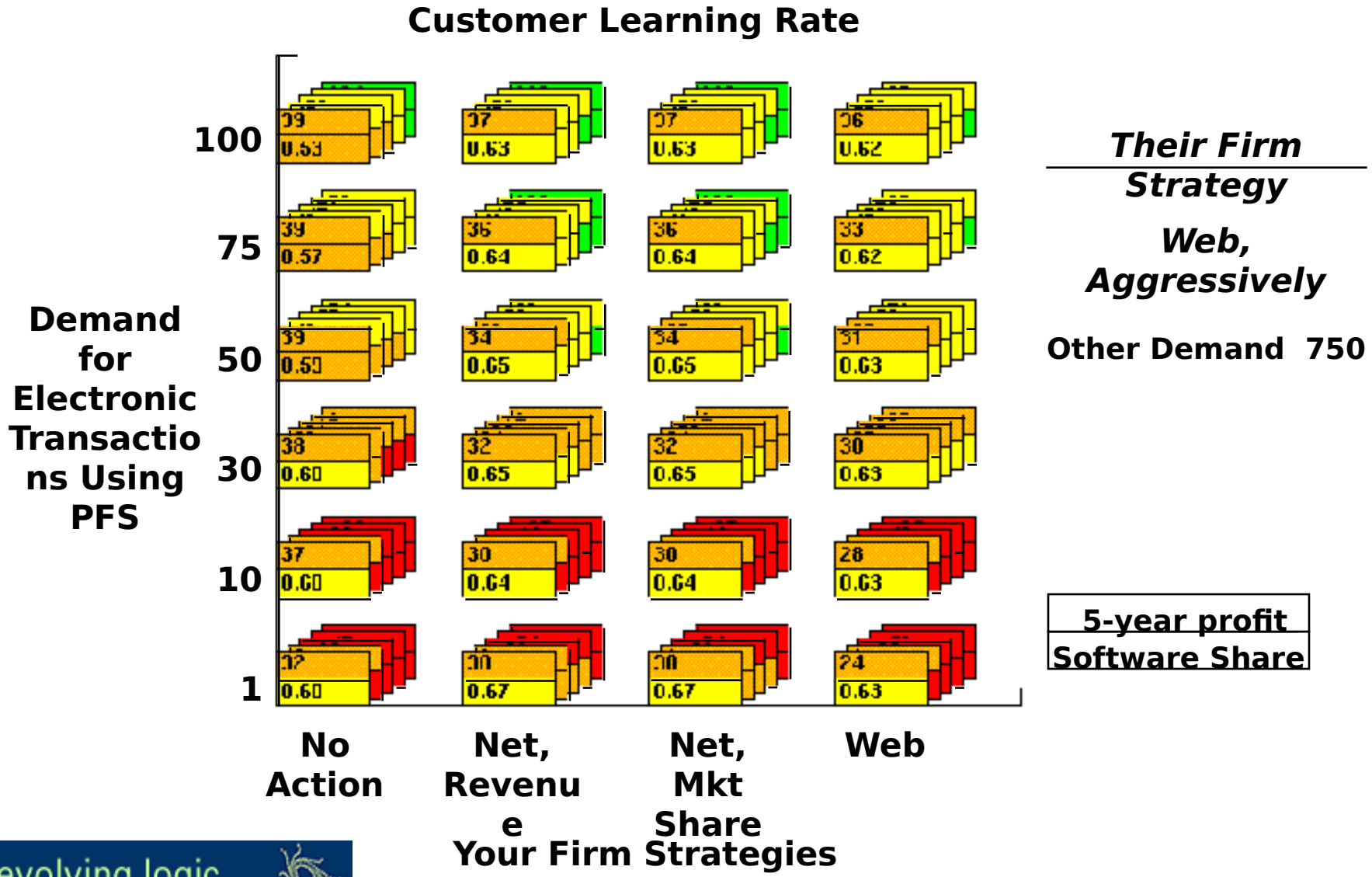
. . . But Your Net Strategies Are Still Best Against an Aggressive Competitor



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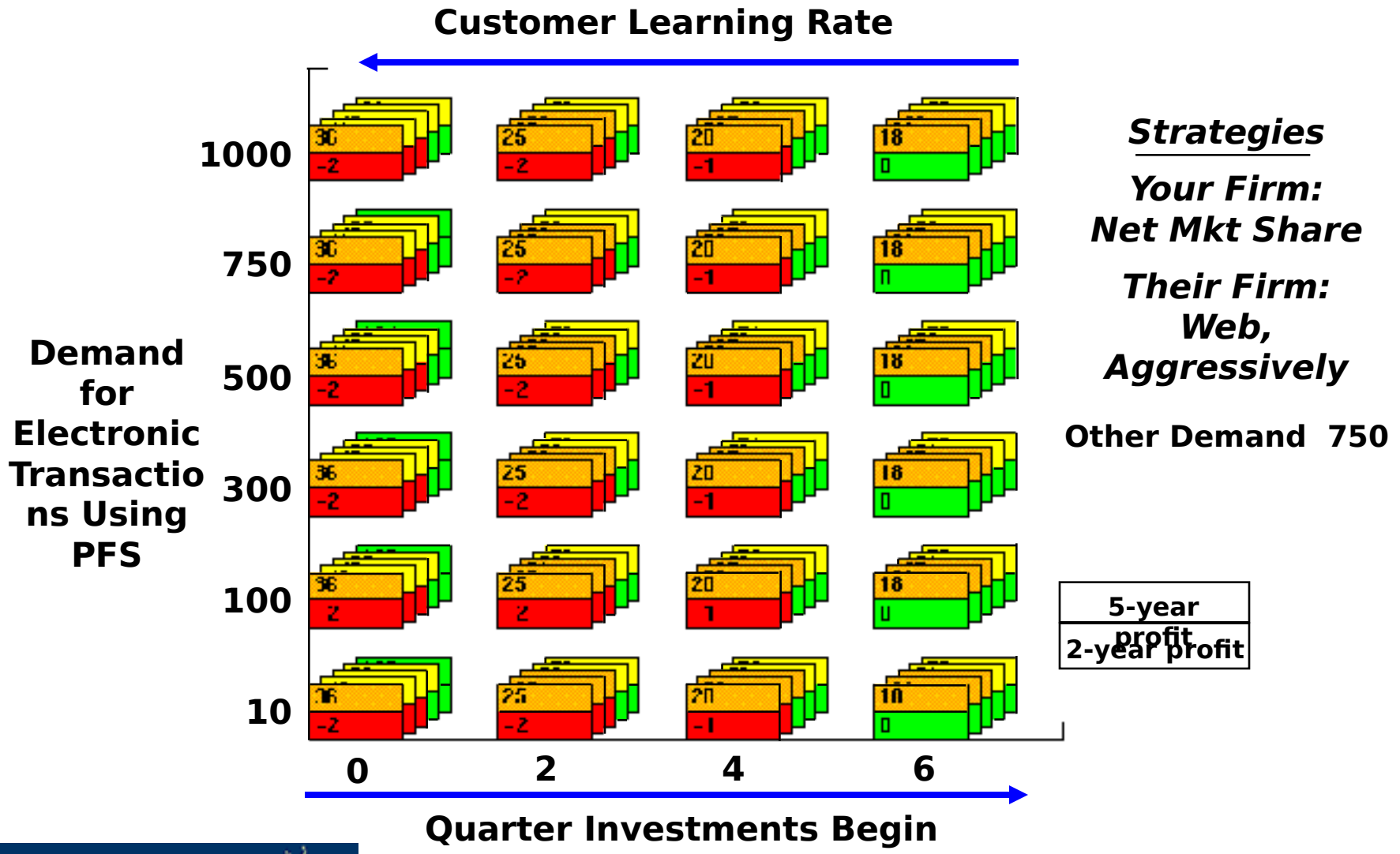
Increasing Returns Mean an Early Decision



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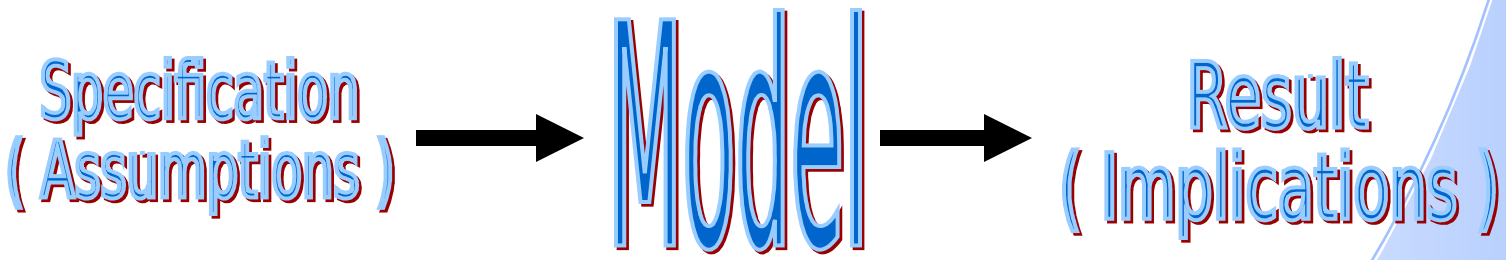
Exploratory Modeling in the Small



Finite number of cases (what - if experiments)

Are used to reason (iteratively, inductively, adversarially) about universal properties of the Model (map, function)

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an appropriate framing of the problem

- People create models to assist in tracing through the complex implications of available information
- Any model embodies assumptions (implicit or explicit) that bound its usefulness
- Reasoning that uses model results mostly deals with the assumptions of that model
- Reasoning thus often involves a series of models, often derived from or constructed in response to, one another
- Model revision means reframing the problem, adding and deleting concepts, changing the dimensions of the spaces of experiments to be explored

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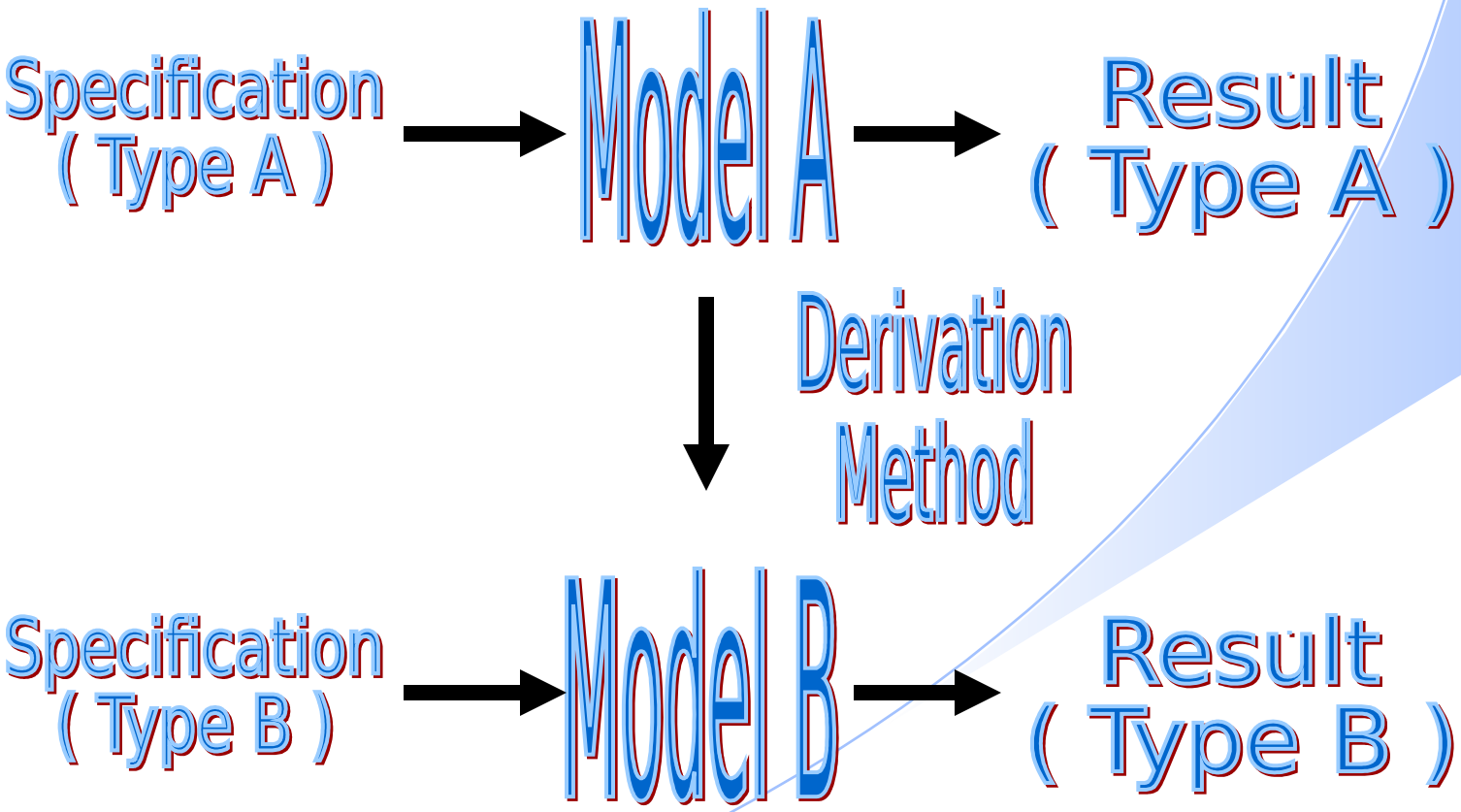
Exploratory Modeling in the Large



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